Storm Track Predictability from Seasonal to Decadal Scales

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Compo, G.P., and P.D. Sardeshmukh, 2004, J. Climate, **17**, 3701-3270.

Outline

1. Introduction to Northern Hemisphere storm tracks and ENSO effects
2. Studying predictability, precipitation, and storm tracks
3. Storm Track Model
4. Actual and expected skill for predicting storm track anomalies
5. Decadal storm track anomalies
6. Forecasting forecast skill

Data and Method

NCEP MRF9: T40L18

JFM integrations: Climatological and actual and idealized ENSO		570 members
1950-94 integrations:	Global SSTs (GOGA)	13 members
(monthly)	30ºN-30ºS Pacific SSTs (POGA)	9 members

*NCAR CCM3:*T42L18

1950-99 integrations:	Global SSTs (GOGA)	12 members
(monthly)	Tropical SSTs (TOGA)	11 members

NCEP-NCAR reanalysis dataset:T62L28

1950-1999

Storm tracks are computed directly from Fourier power spectrum summed over 2.0 to 6.9 days and are also computed using an Empirical Storm Track Model.

500 mb storm track (January-March)
2-7 day bandpass filtered

Bandpass filtered eddies correspond to storm tracks (Blackmon et al 1977; Wallace et al 1988; Chang et al 2002; Hoskins and Hodges 2002)

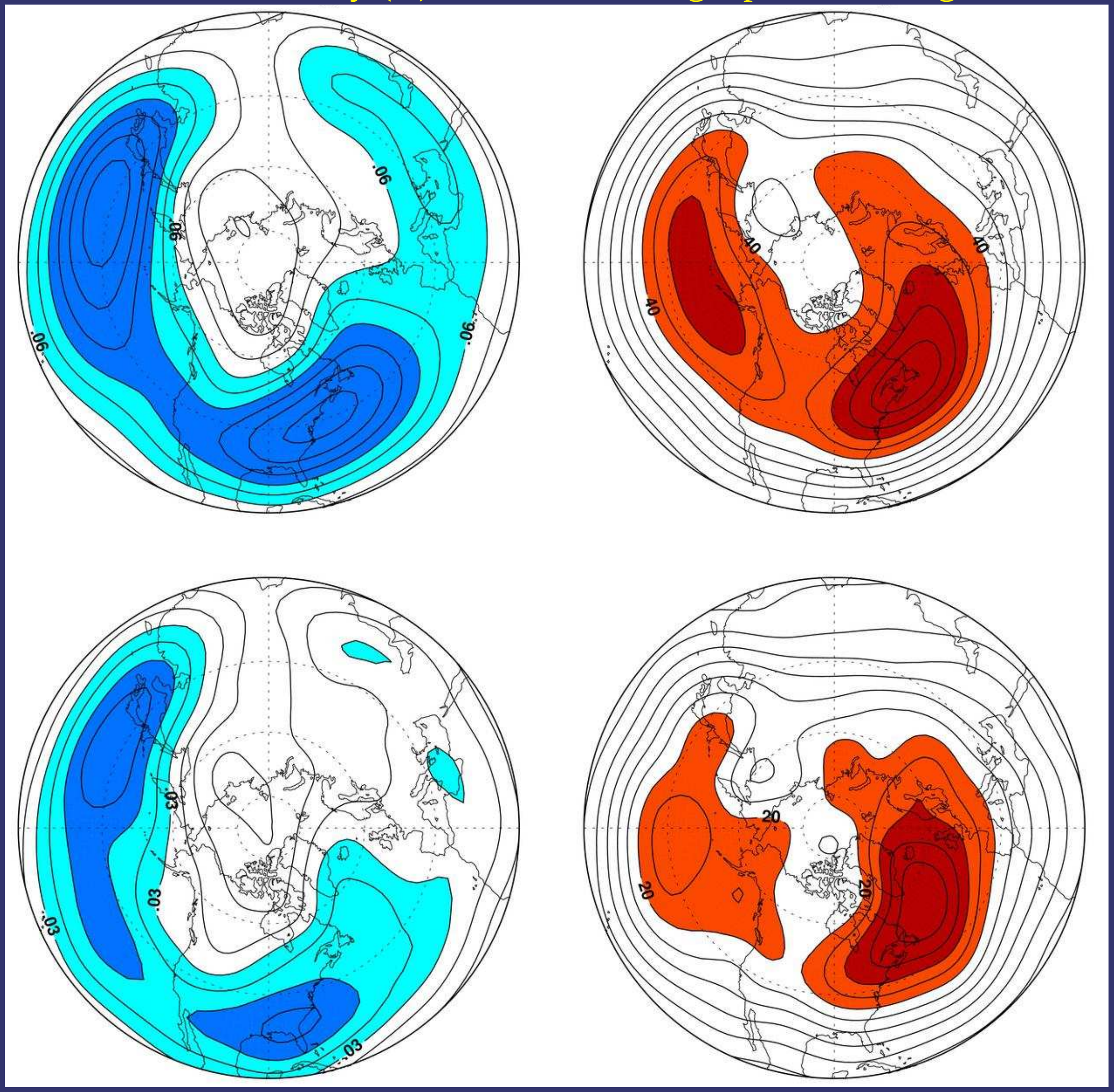
ENSO plays a role in storm track interannual variability (Fraedrich 1990; Hoerling and Ting 1994; Strauss and Shukla 1997; May and Bengtsson 1998)

vertical velocity (ω)

geopotential height

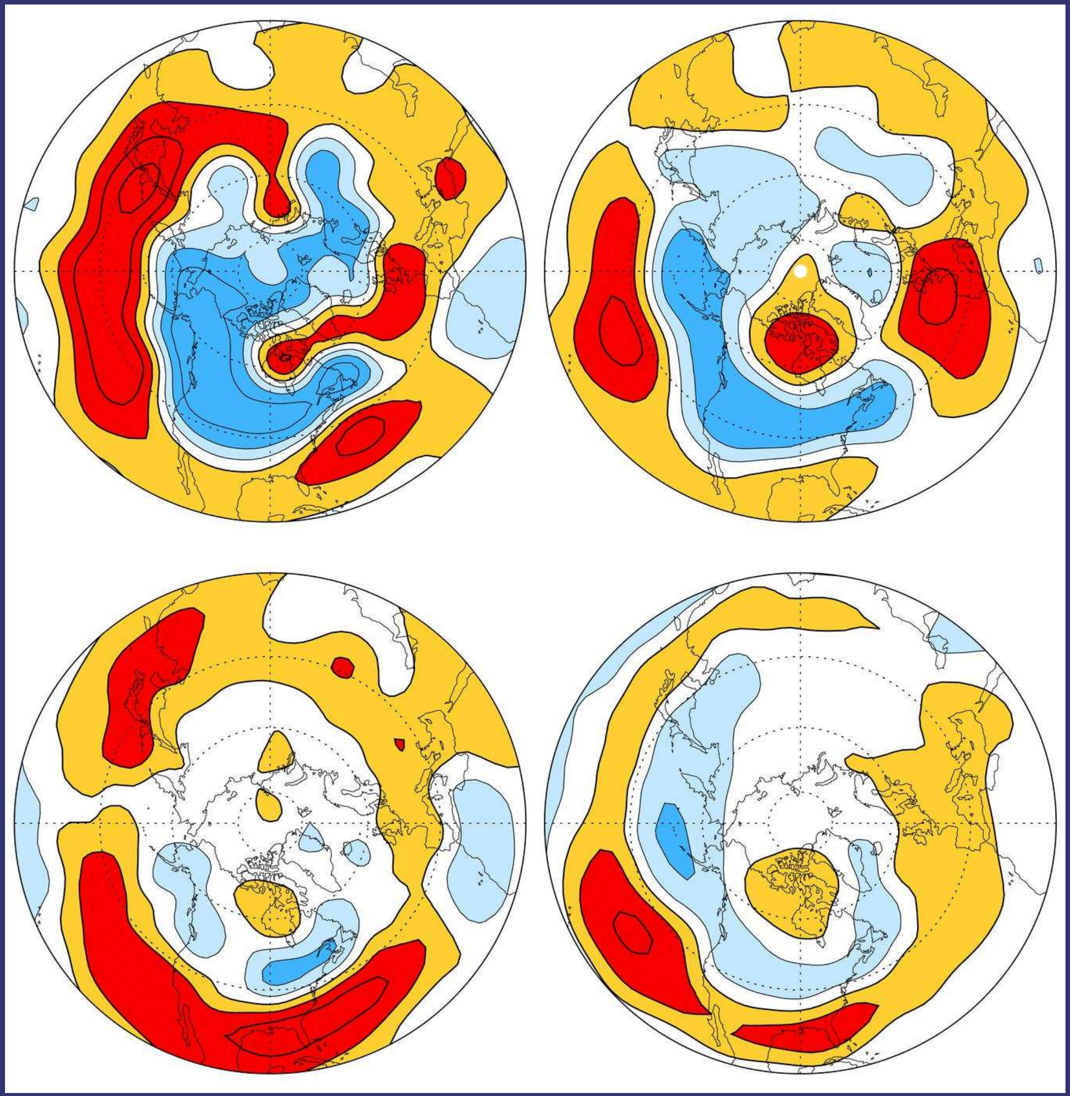
Seasonal mean

Interannual standard deviation



ENSO has a significant effect on stormtracks

El Nino anomalous stormtracks (JFM) 2 to 7 day standard deviation

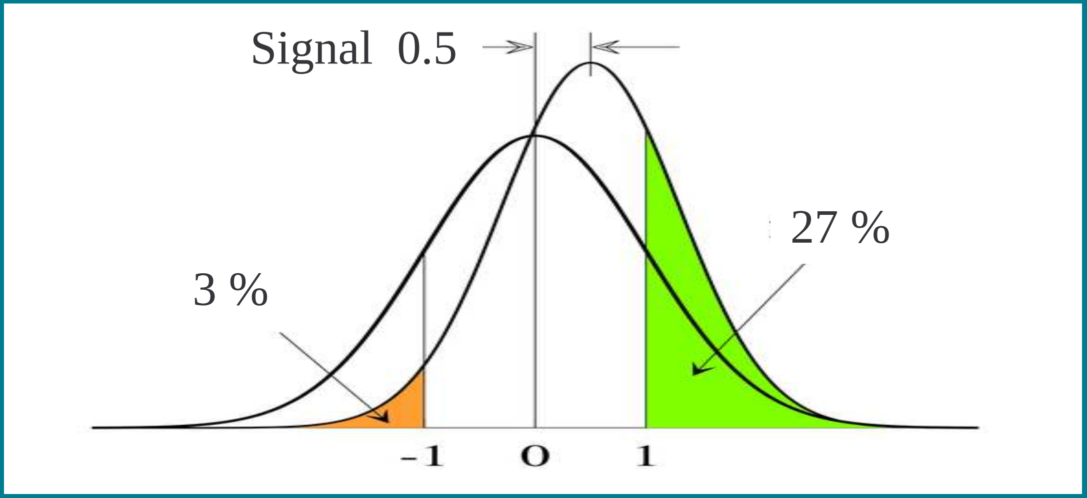


from Compo, Sardeshmukh, and Penland (J. Climate 2001)

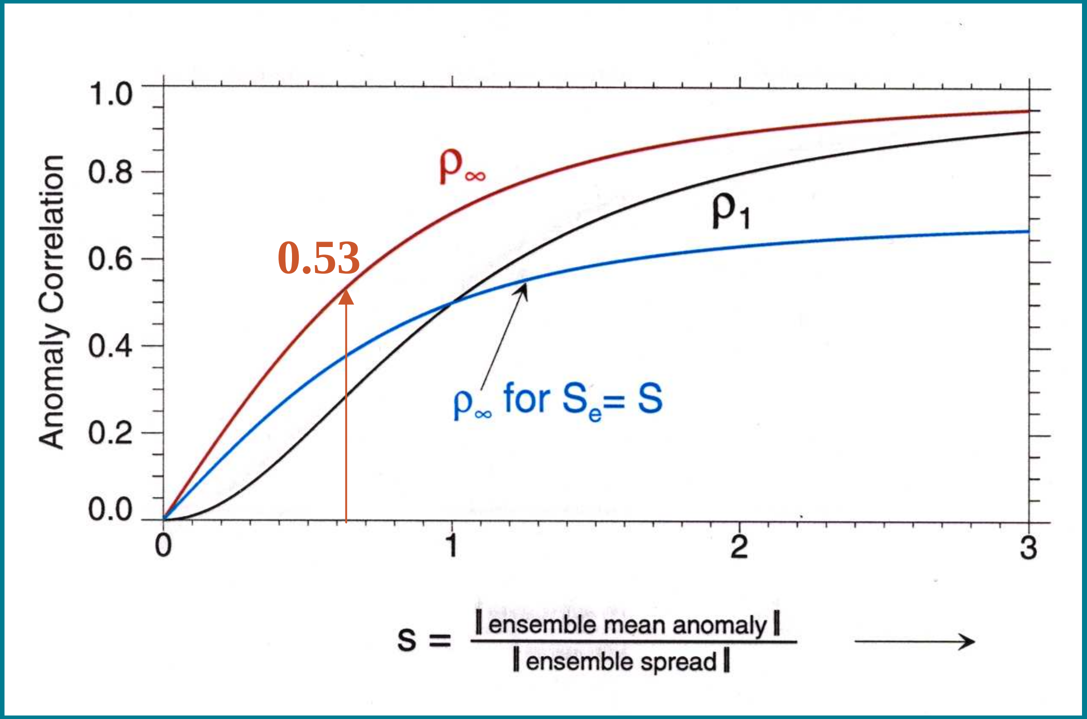
Is it predictable?

Predict • ability

The ability to predict a *different range of possibilities* than the climatological range



Expected forecast skill as a function of signal to noise ratio



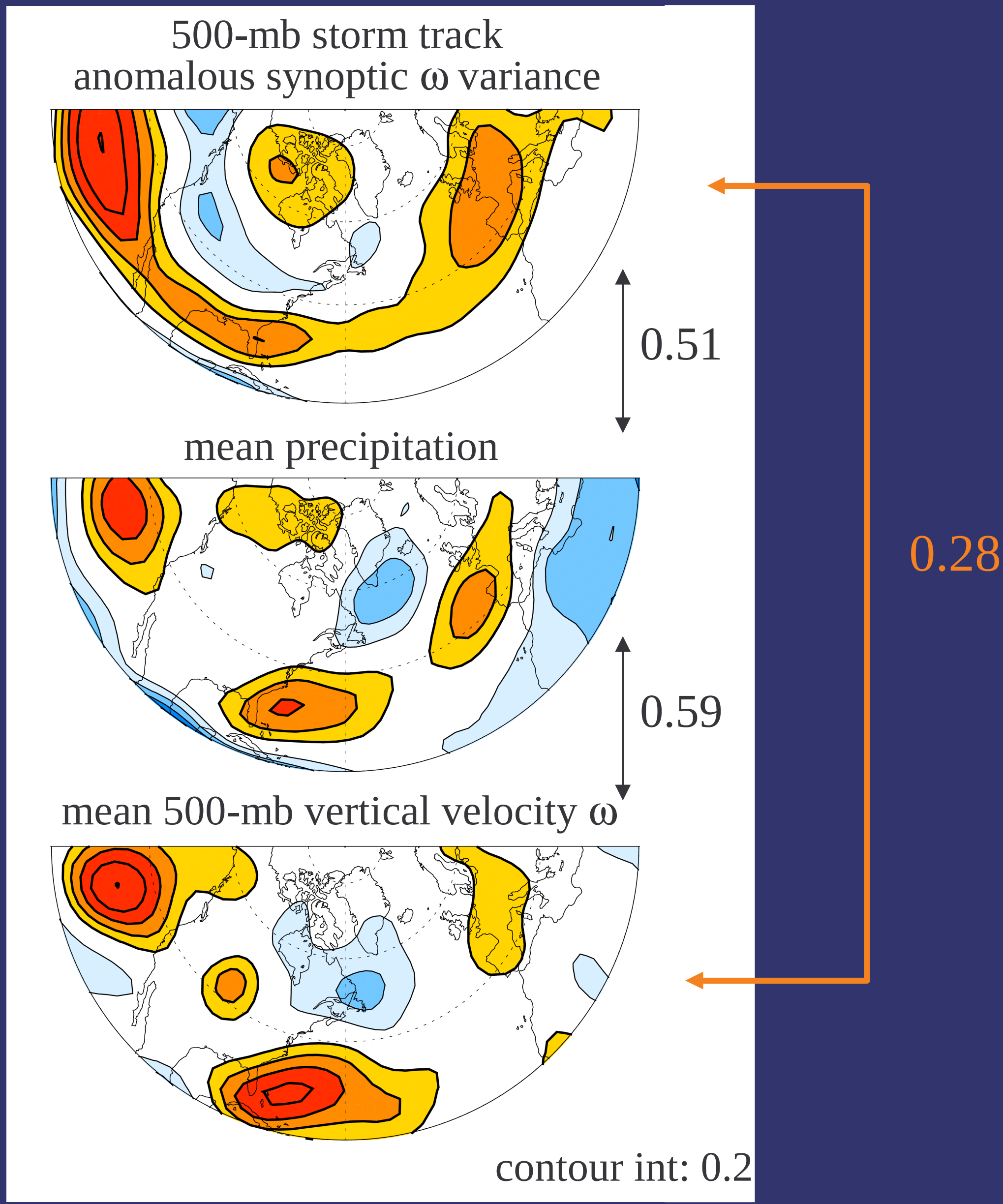
from Sardeshmukh, Compo, and Penland (J.Climate 2000)

SST-forced Signal to noise ratios *S* in JFM 1987

The predictability of ω storm tracks is important for the predictability of seasonal mean precipitation.

Just as important as seasonal mean 500 mb ω.

60-member ensemble GCM runs with El Nino (JFM 1987) SST forcing.



An Empirical Linear Storm Track Model (STM)

$$\underline{\mathbf{y}} = \boldsymbol{G}\underline{\mathbf{x}} + \varepsilon$$

$\underline{\mathbf{x}}$ = winter mean 200 mb height anomalies (40 EOFs)
$\underline{\mathbf{y}}$ = winter mean storm track anomalies (50 EOFs)
(anomalous variance of 2-to-7 day filtered 500 mb ω)

G is estimated from large (570-member) ensembles of seasonal NCEP GCM runs with climatological mean SSTs and also observed and idealized ENSO SST forcing.

Chang and Fu (2003), Peng et al (2003), Compo and Sardeshmukh (2004)

Design of Study

The linear STM is first tested for its ability to reproduce the nonlinear NCEP GCM's (60-member) ensemble-mean storm track responses to warm and cold ENSO SST forcing in 1987 and 1989, given only the GCM's ensemble-mean 200 mb height responses.

It is then used to predict observed winter-mean and 5-winter-mean storm track anomalies during 1950-1999, given :

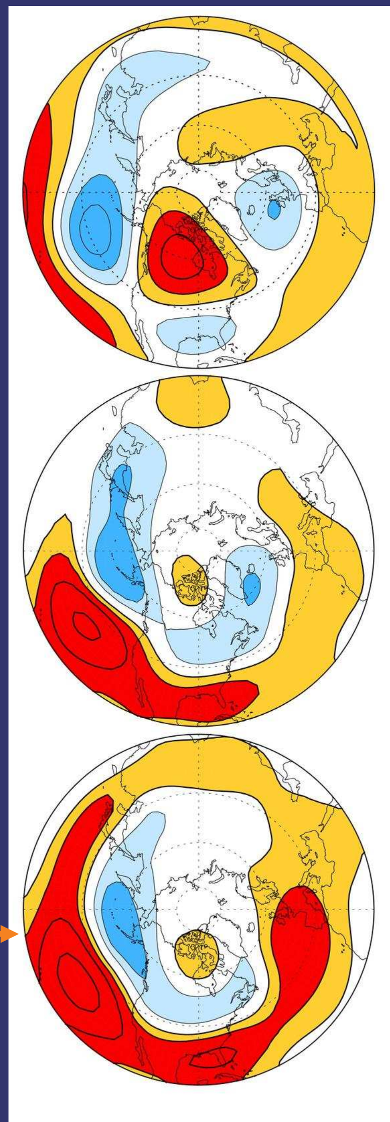
1. The observed 200 mb height anomalies, and

2. The NCEP and NCAR GCMs' (~12-member) ensemble-mean 200 mb height responses to
   (a) anomalous Global SST forcing (GOGA), and
   (b) anomalous Tropical SST forcing (TOGA)

   These predicted storm anomalies are interpreted as the "predictable" SST-forced part of the anomalous storm track in each winter and 5-winter mean.

Testing the linear STM

1987
El Nino

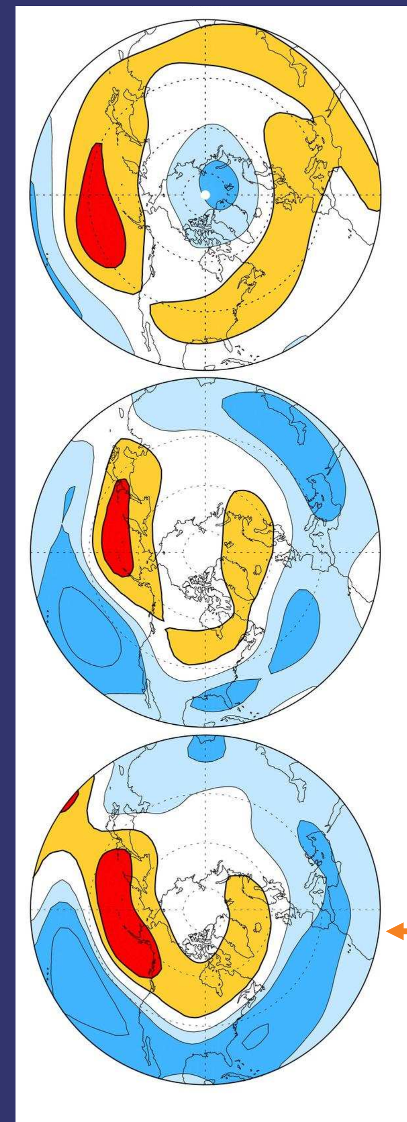


GCM's
60-member
ensemble mean
200 mb height
response

Linear STM's
500 mb ω
Storm track
response

GCM's
ensemble-mean
500 mb ω
Storm track
response

1989
La Nina



0.9

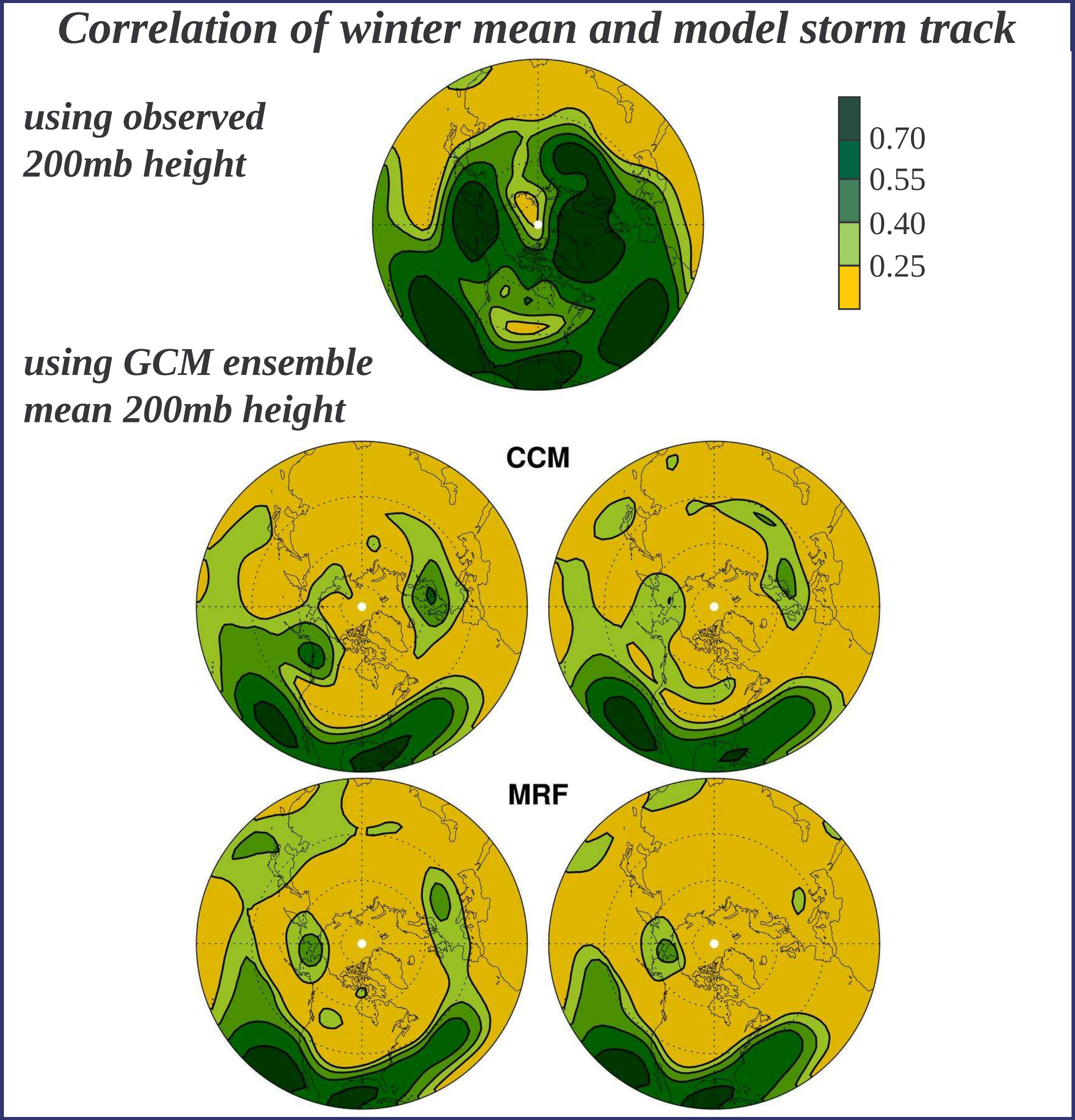
0.9

C.I. 20 m for height, ~ 10 mb/day for storm track

Skill of winter-mean storm track anomaly "predictions" made by the linear STM

Predictable part is associated mostly with tropical SST forcing

CI: 0.15
Starting at 0.25



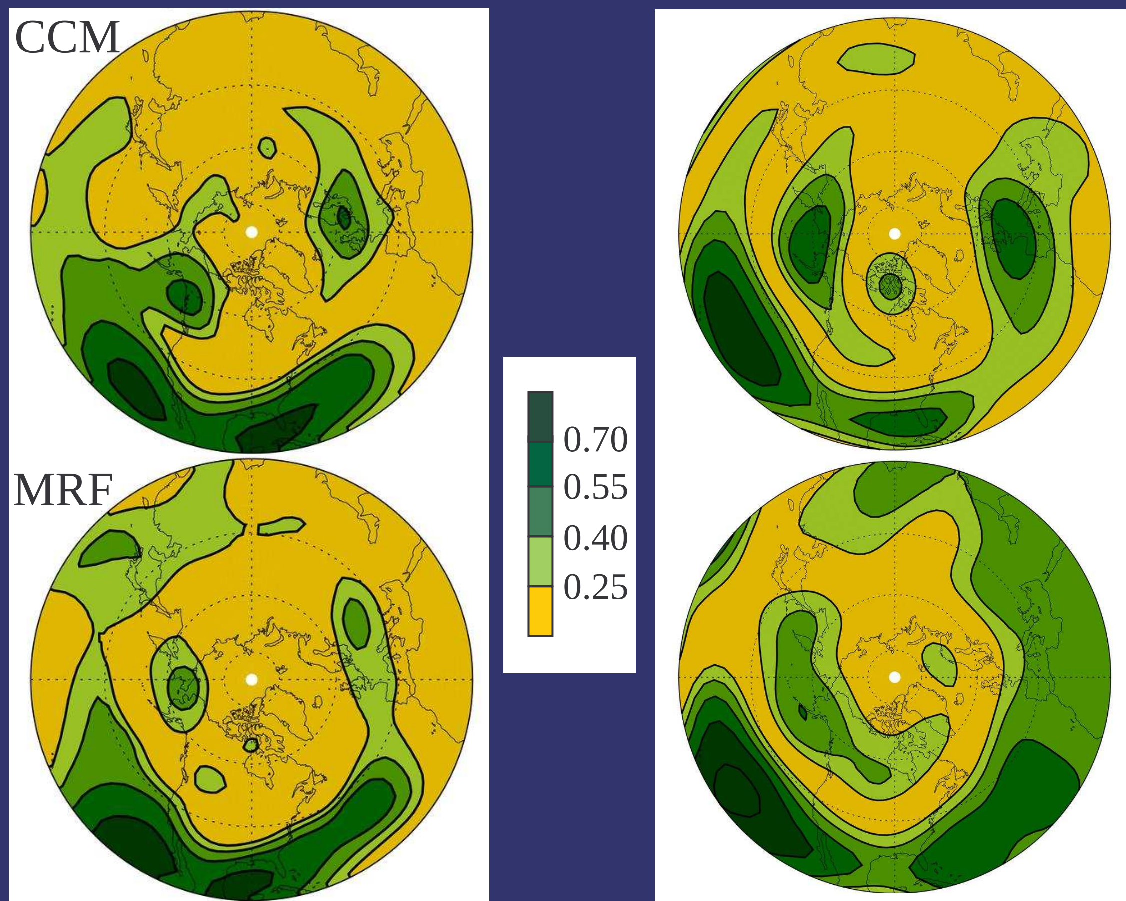
Global SSTs Tropical SSTs

SST-forced storm track predictability
(local anomaly correlation)

x=SST forced
200 mb Z

y=Gx

50 winters



1987 El Nino

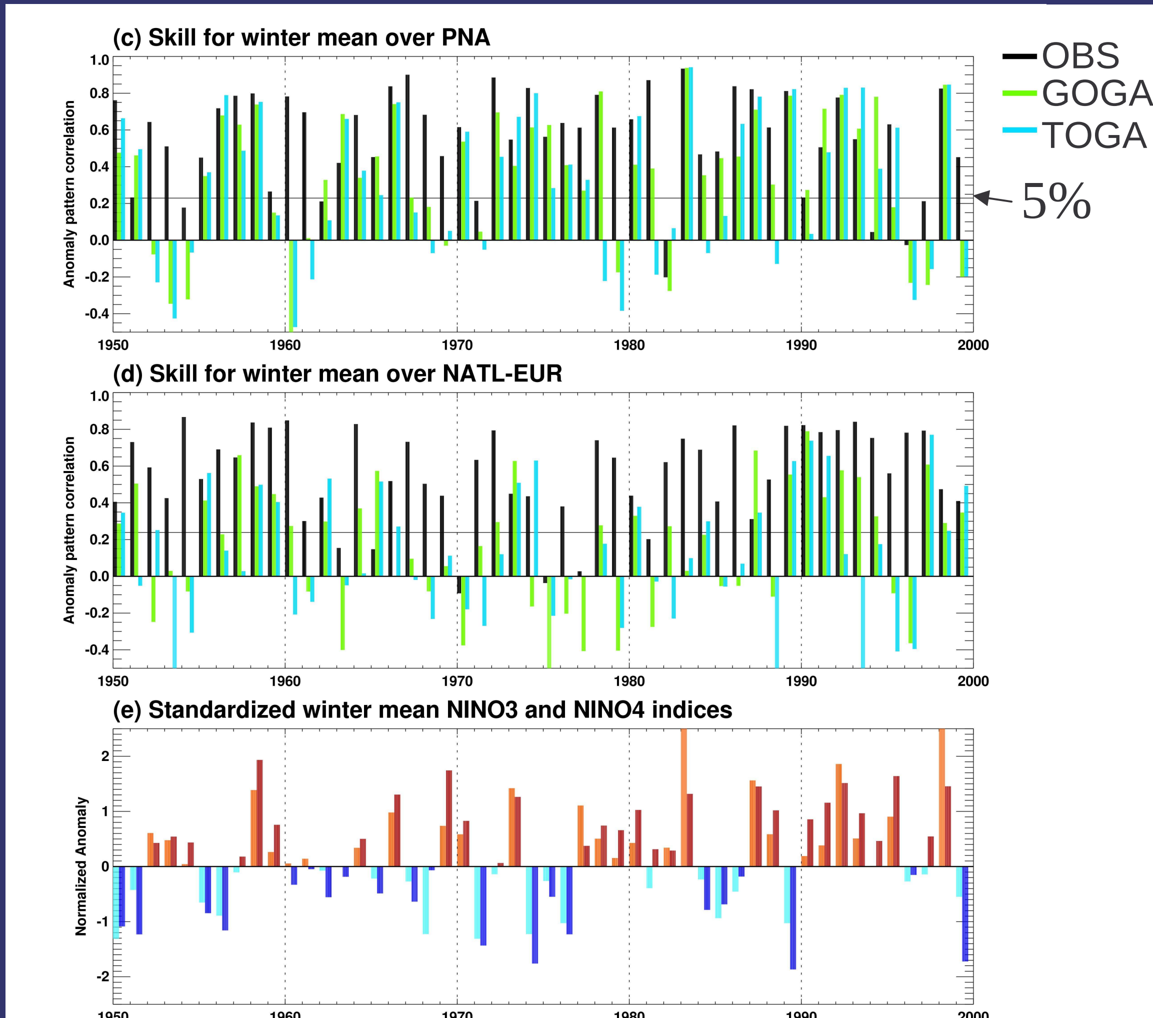
1989 La Nina

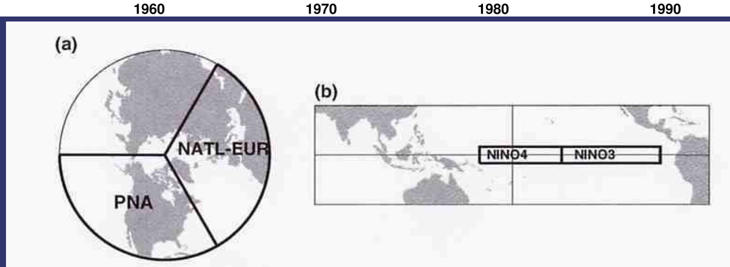
60 MRF members

GCM sensitivity

Case dependence

Skill in Predicting Observed Anomalous Stormtracks





PNA Sector

Skill of GOGA and TOGA significant and strongly associated with ENSO.

North-Atlantic/Europe

Lesser skill

More skillful years than just ENSO over PNA (26).

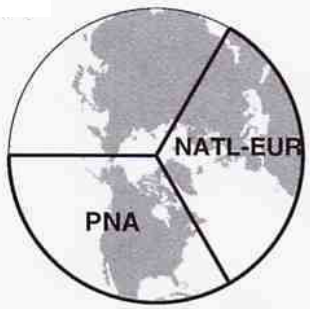
Average storm track pattern correlation stratified by ENSO indices

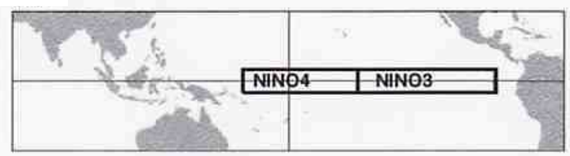
Both NINO3 and NINO4 are important for skillful stormtrack predictions

NINO4 is somewhat more important in PNA region.

Weak-ENSO with large NINO4 can have skill over PNA sector.

	|NINO3| ≥ 1σ	|NINO3| < 1σ	|NINO3| ≥ 1σ	|NINO3| < 1σ
	|NINO4| ≥ 1σ	|NINO4| ≥ 1σ	|NINO4| < 1σ	|NINO4| < 1σ
Number of Cases	11	9	2	28
PNA				
TOGA	*0.68*	*0.39*	0.13	0.11
GOGA	*0.61*	*0.36*	0.23	*0.25*
OBS	*0.72*	*0.57*	*0.65*	*0.50*
NATL-EUR				
TOGA	*0.29*	0.11	-0.12	0.05
GOGA	*0.30*	0.19	-0.24	0.13
OBS	*0.57*	*0.57*	0.27	*0.57*





Decadal storm track anomalies

Decadal storm track variations reported in several studies (Hurrell and van Loon 1997, Graham and Diaz 2001, Chang and Fu 2002, 2003, Harnik and Chang 2003).

Omega stormtrack not reported.

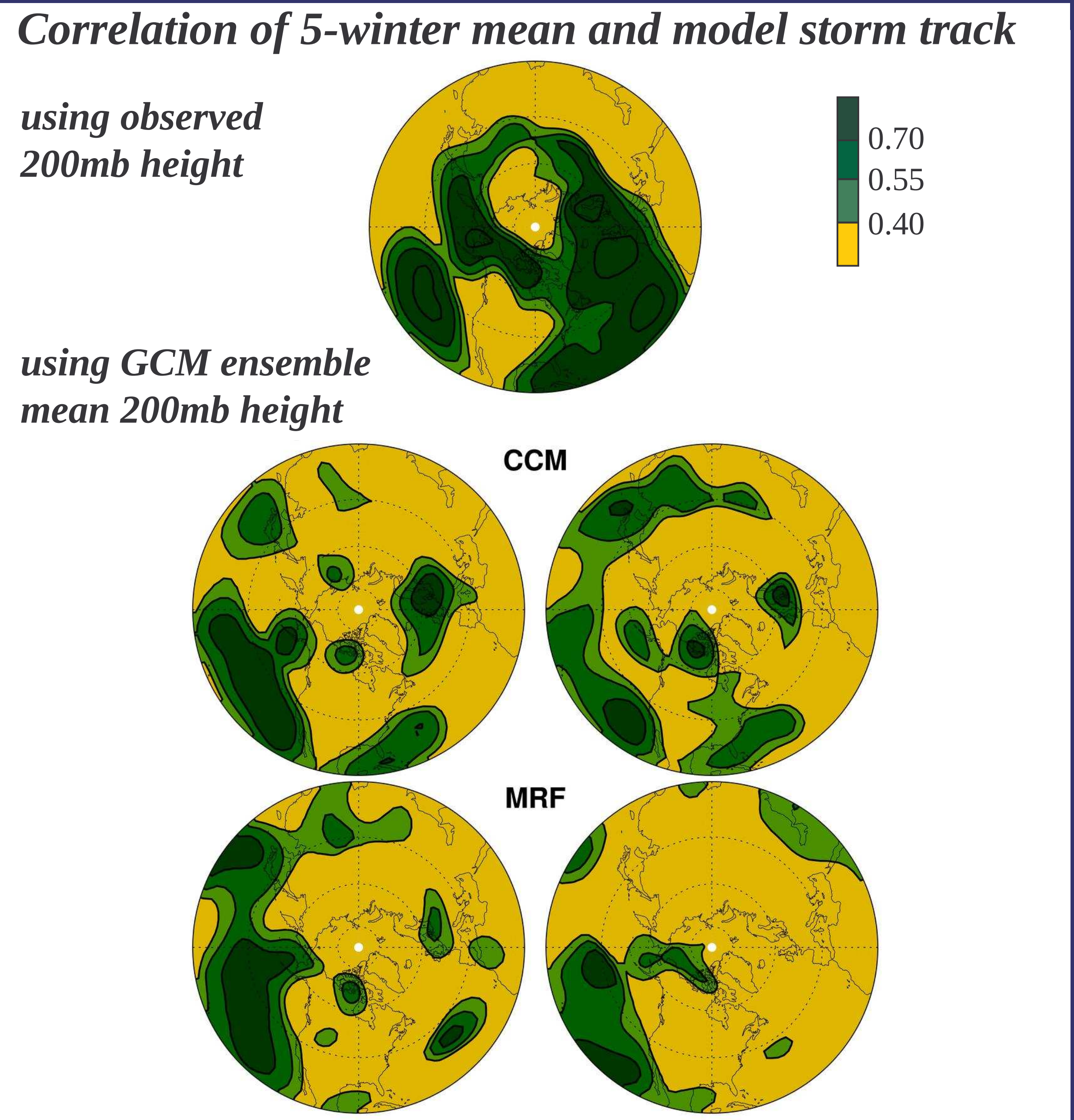
Relationship to global SST variations not reported.

Use STM to examine consistency between GCM and observed 5-winter mean stormtrack anomalies.

Skill of 5-winter-mean storm track anomaly "predictions" made by the linear STM

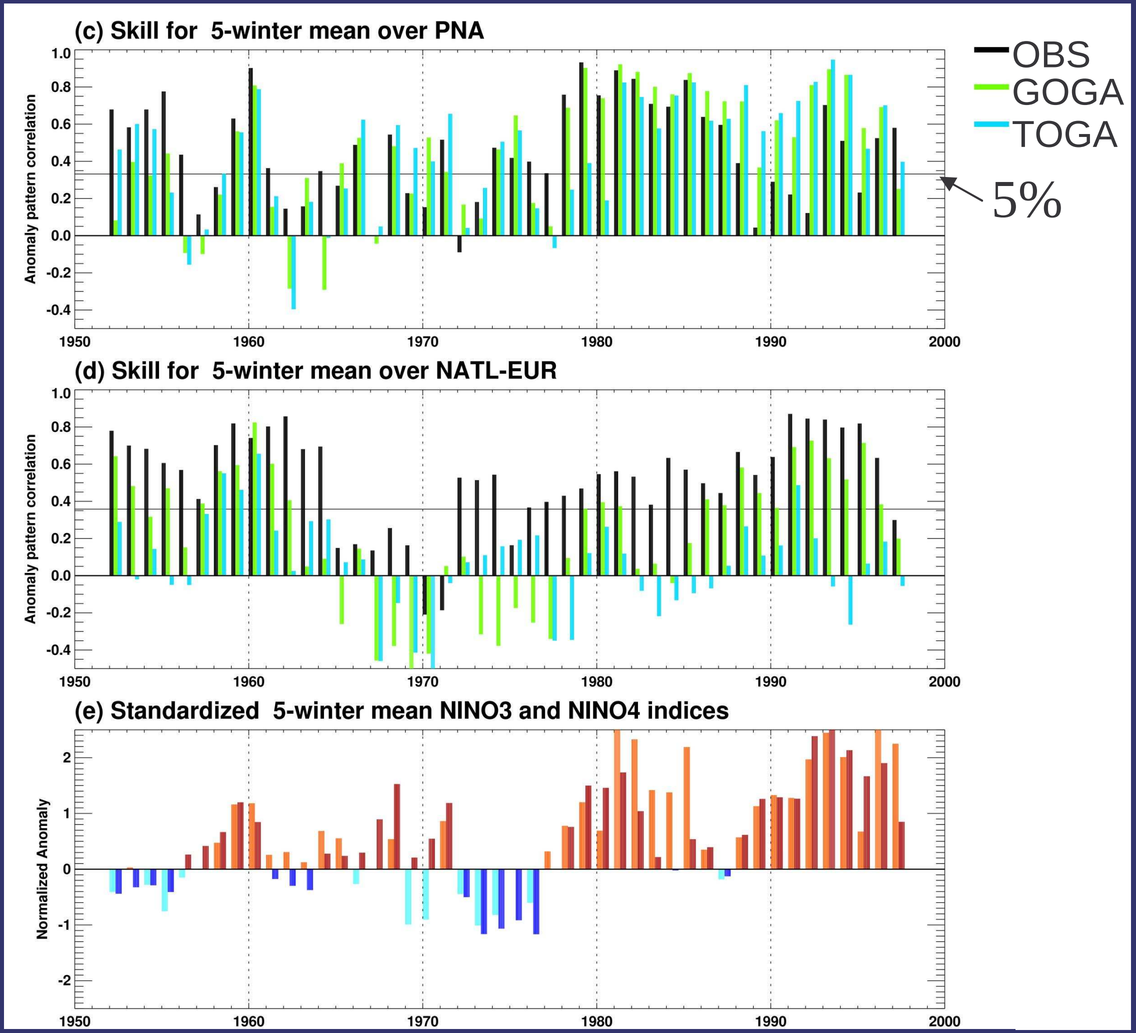
SST-forced component is associated mostly with tropical SST forcing

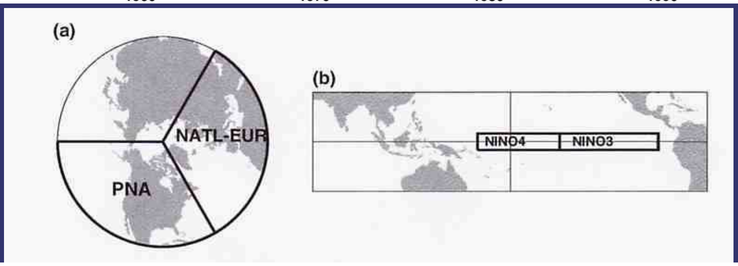
CI: 0.15
Starting at 0.4



Global SSTs Tropical SSTs

Skill in Simulating 5-winter mean Observed Stormtracks





PNA Sector

Skill of GOGA and TOGA significant and strongly associated with low-frequency ENSO.

North-Atlantic/Europe

No significant skill

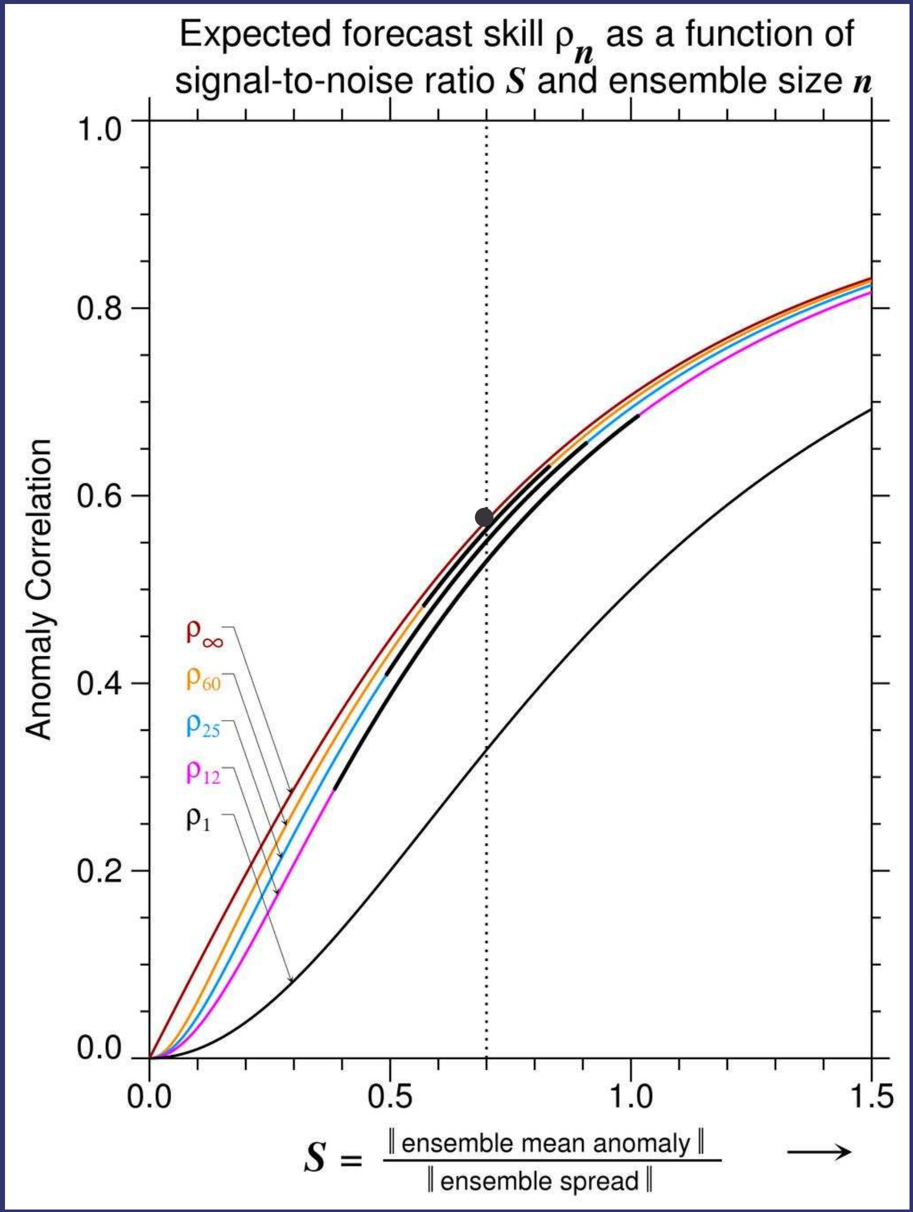
Forecasting forecast skill

Thick black curves show uncertainty in expected skill ρ_n for $S = 0.7$ from using n-member ensembles.

Note!!

The uncertainty is much larger for small n than the smaller overall ρ_n .

Averaging over cases can reduce this uncertainty.



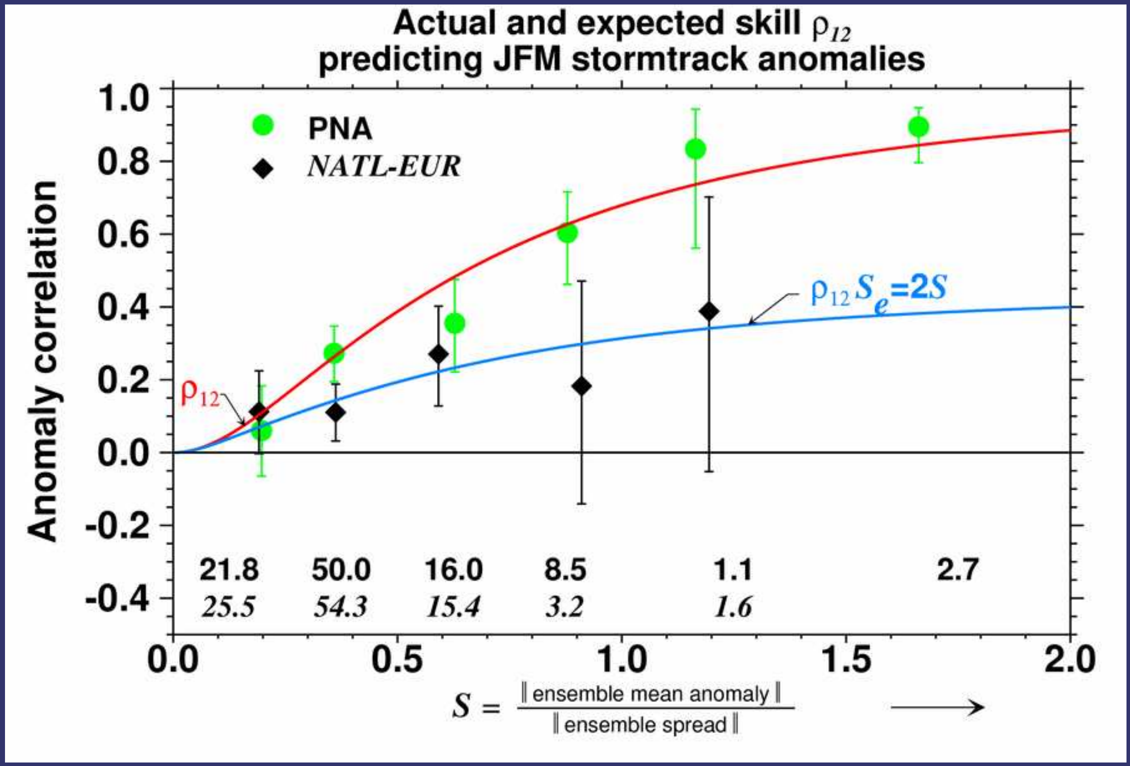
Observed vs expected skill for Northern Hemisphere Storm Track Anomalies

In Pacific sector, actual skill is consistent with signal to noise ratios

but not in Atlantic sector….

Is this because of errors in:
1. Storm Track Model, or
2. GCMs' 200 mb Z response in the Atlantic?

Latter is more likely, given the STM's reproduction of the GCM's ensemble mean Atlantic storm tracks in 1987 and 1989.



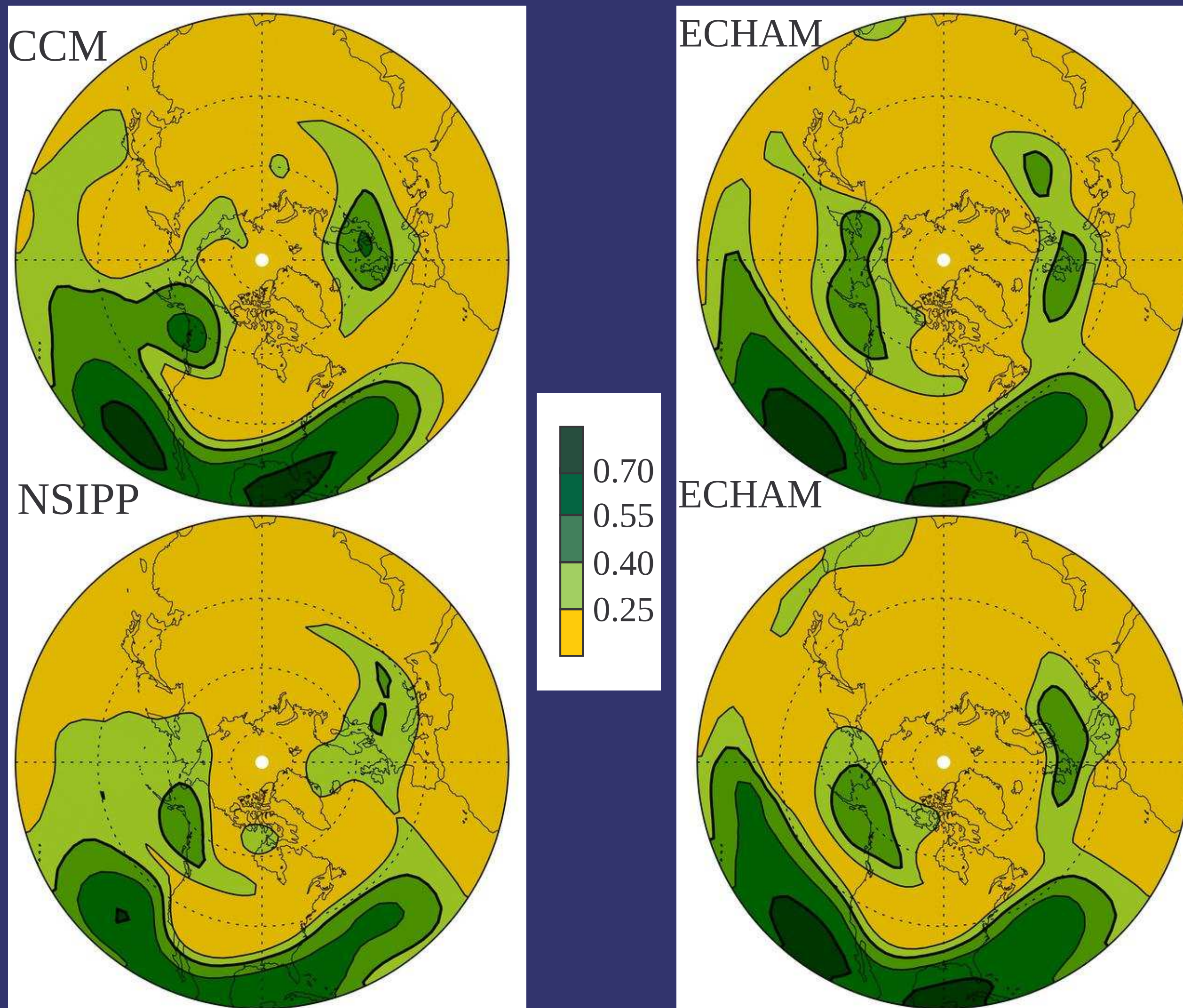
Symbols show actual pattern correlations

SST-forced storm track skill is very similar in older and newer GCMs…

x=SST forced
200 mb Z

y=Gx

50+ winters

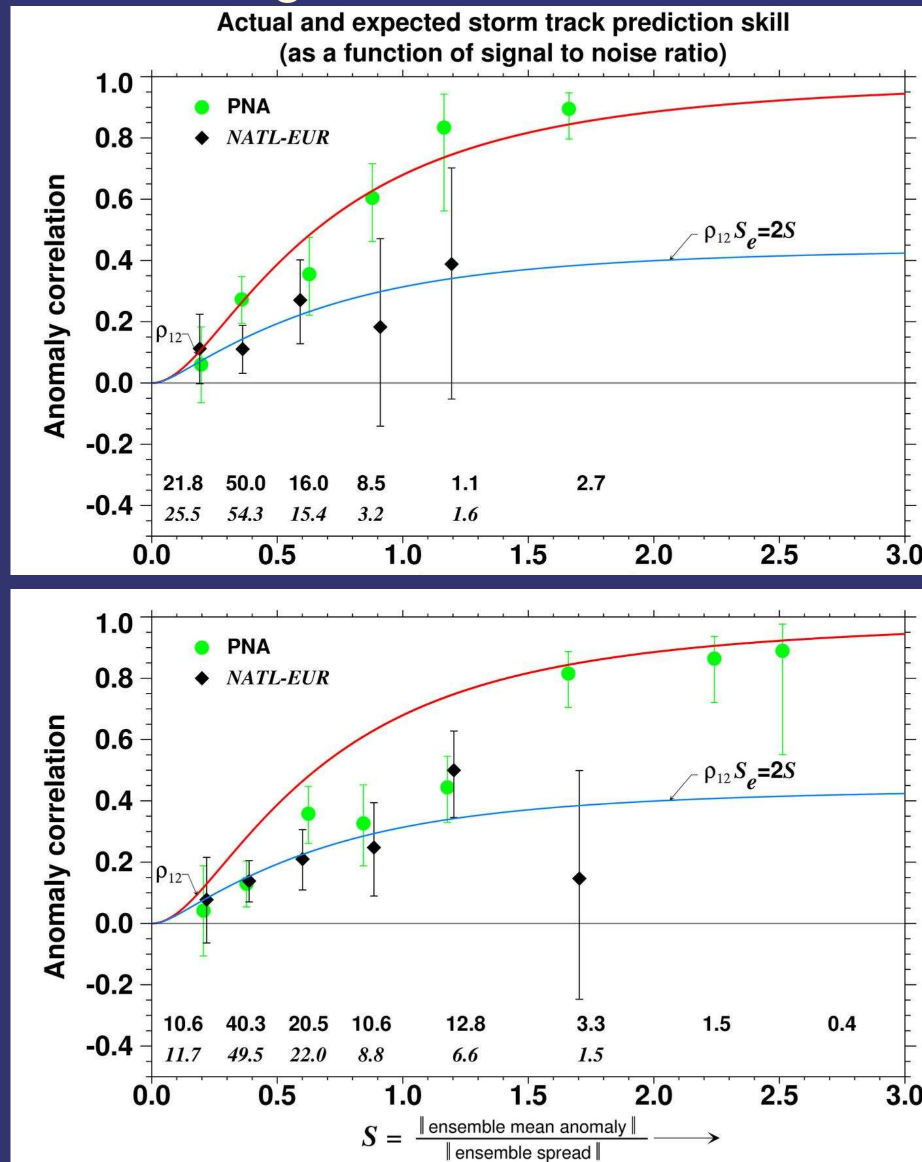


12 members

12 members

Local anomaly correlation

But actual skill of newer models is not necessarily more consistent with signal to noise ratios!



MRF9
CCM3

ECHAM
NSIPP

For newer models,

In Pacific sector,
actual skill is consistent with signal to noise ratios only for large *S*

and not at all in Atlantic sector….

Symbols show actual pattern correlations

Summary

1. Our *linear* STM can reproduce a nonlinear GCM's storm track response to ENSO, given only the GCM's 200 mb height response.

2. The linear STM has been used to estimate the local and regional predictability of winter-mean and 5-winter-mean storm track anomalies. There is substantial predictability in the Pacific sector, much less so in the Atlantic sector.

3. Most of this predictability is associated with tropical SST forcing.

4. The predictability estimates are more reliable in the Pacific than in the Atlantic sector, *where they are inconsistent with estimated signal to noise ratios, even for newer models*.